DESIGN AND TESTING OF SPORT PROSTHETIC FOOTS FOR AMPUTEES

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INTRODUCTION

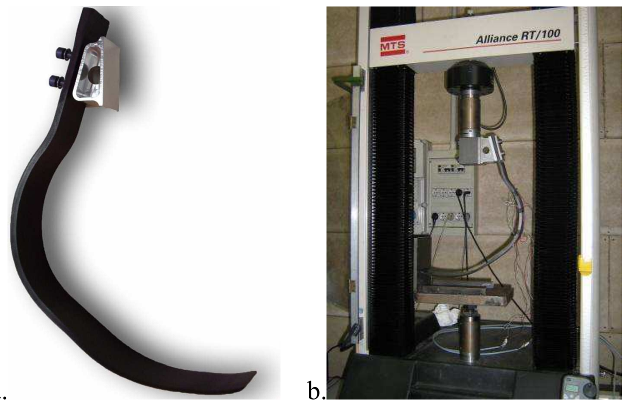
Object of this work is a foot prosthesis in carbon fiber for agonistic running of disable athletes. A general description of the evolution of the prostheses in these last years is proposed in [1]. The tested prosthesis is composed of a single multi-layer lamina, with a curvilinear shape, as shown in Fig. 1.a. The prosthesis replaces the athlete's foot and tibia areas and aims to maintain the functionality of the muscle-tendon group of the foot: its elasticity is important for the athlete and is supposed to be comparable with the one of a sane leg. This can be obtained by the used materials, the prosthesis geometry and the position of the socket, which connects it to the upper part of the leg. The tested prosthesis is made of carbon fiber layers in a epoxy resin matrix; the external part of laminate is then covered with a double layer of tissue.

The evaluation of strenght of sport prostheses is essential because their collapse during a highly dynamic loading action might produce devastating consequences for the athetes

The overall aims of this work are the design optimization and the check of the static and fatigue strength of the prosthesis according to the standard [2]. This standard describes the procedures to be followed to perform tests on lower limb prostheses and to assess their validity. A single force simulating the load components that normally are produced during walking, is applied during the tests to obtain mixed loads on the prosthesis.

METHODS

With the aim of experimentally testing the prosthesis and of checking its mechanical characteristics, structural tests are performed by the application of static and fatigue tests. The upper part prosthesis corresponding to the knee area, is clamped to a testing machine applying the load for the static tests. The experimental setup for the static test is shown in Fig. 1.b.



a. b.

Figure 1: Tested prosthesis and experimental setup for the static tests.

For the fatigue test, the load is applied by a hydraulic actuator. Appropriate equipments are built up and used for a systematic and simple application of the load during these tests.

The results of the static test are then used to validate a numerical FE model; in this analysis, the geometry of the prosthesis is checked and collected by a sampler. The mechanical characteristics of the laminate material are obtained from experimental tests. Tensile tests on specimens cut out from the prosthesis composite material allowed the determination of the elastic modulus and of the Poisson ratio to be used in the numerical simulations. By means of a check at the optical microscope, the experimental positions of the layers in the epoxy resin matrix are moreover obtained. In the numerical model, the prosthesis is compressed against a rigid surface with contact: in this way, the analysis simulates the real loading phase as in the experimental static test.

A final simulation with the numerical model is performed to simulate the running phase of the prosthesis based on the forces profiles of [3]. The prosthesis is clamped at its upper part and a variable load in its magnitude and application point is applied: in such a way it is possible to check the energy that the athletes must spend during running.

RESULTS AND DISCUSSION

The crosshead displacements and the strains in different points, where strain gauges were applied, are compared with results of the numerical simulation in order to validate the FE model. This numerical model is then used to assess the influence of different parameters, enabling the use of this numerical simulation for a design optimization. The model can give useful information on the influence of the mechanical properties of the composite in the different directions, in terms of stresses, strains and displacements in the single layers. Since the model can check prosthesis displacements, stresses and strains, it is also used to evaluate the influence in the number and thickness of the layers of carbon fiber laminas and of the external tissue.

CONCLUSIONS

By means of the results of the performed experimental tests, a numerical FE model of the prosthesis is validated and used for its optimization. The proposed model is then used to improve the performances of the tested prosthesis.

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